Original research

Extreme heat and work injuries in Kuwait's hot summers

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ABSTRACT

Background Hot, desert Gulf countries are host to millions of migrant workers doing outdoor jobs such as construction and hospitality. The Gulf countries apply a summertime ban on midday work to protect workers from extreme heat, although without clear evidence of effectiveness. We assessed the risk of occupational injuries associated with extreme hot temperatures during the summertime ban on midday work in Kuwait.

Methods We collected daily occupational injuries in the summer months that are reported to the Ministry of Health's Occupational Health Department for 5 years from 2015 to 2019. We fitted generalised additive models with a quasi-Poisson distribution in a time series design. A 7-day moving average of daily temperature was modelled with penalised splines adjusted for relative humidity, time trend and day of the week.

Results During the summertime ban, the daily average temperature was 39.4°C (±1.8°C). There were 7.2, 7.6 and 9.4 reported injuries per day in the summer months of June, July and August, respectively. Compared with the 10th percentile of summer temperatures in Kuwait (37.0°C), the average day with a temperature of 39.4°C increased the relative risk of injury to 1.44 (95% CI 1.34 to 1.53). Similarly, temperatures of 40°C and 41°C were associated with relative risks of 1.48 (95% CI 1.39 to 1.59) and 1.44 (95% CI 1.27 to 1.63), respectively. At the 90th percentile (42°C), the risks levelled off (relative risk 1.21; 95% CI 0.93 to 1.57).

Conclusion We found substantial increases in the risk of occupational injury from extremely hot temperatures despite the ban on midday work policy in Kuwait. 'Calendar-based' regulations may be inadequate to provide occupational heat protections, especially for migrant workers.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Previous studies have shown that hot ambient temperatures are associated with increased risk of occupational injuries.

⇒ Policy-makers in the hot desert Gulf countries adopted a simple ban on midday work during the summer months.

WHAT THIS STUDY ADDS

⇒ This study provides evidence of substantial increases in occupational injury risk from extremely hot temperatures despite the ban on midday work policy in Kuwait.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The evidence from this study is suggestive that the popular and easy-to-implement 'calendar-based' regulations in the Gulf may not be enough to provide occupational heat protections.

⇒ 'Risk-based' heat standards are needed to protect all workers, but especially migrant workers in the Gulf who may face inequitable harms from more extreme heat brought by climate change.

INTRODUCTION

Climate change has contributed to the last 7 years (2015–2021) being the seven hottest years on record, globally.[1] For countries in the Middle East, like Kuwait, hot summers are entering uncharted extreme heat territory.[2–4] In recent years, Kuwait has regularly recorded hourly and daily temperatures in excess of 50°C and 40°C, respectively. Hotter summers threaten workers' health in Kuwait.[5 6]

Globally, hazardous heat can be detrimental to the productivity and health of workers.[7] Evidence shows that there is increased risk of heat-related illness and traumatic injury with increasing occupational heat exposure.[8 9] Socially disadvantaged workers and migrant workers, in particular, can be disproportionately affected by hazardous heat.[10] These vulnerable workers tend to take risky jobs with little health and safety training, work longer hours, receive less pay, face cultural and language barriers, and fear a looming risk of deportation.[11] They have been found to sustain greater rates of occupational injuries.[12]

In Kuwait, where two-thirds of the population consists of non-nationals and migrant workers, a ministerial law in 2015 banned employees from working in open outdoor spaces from 11:00 to 16:00 hours from 1 June to 31 August of every year.[13] All Gulf countries (Saudi Arabia, Bahrain, Qatar, United Arab Emirates and Oman) have adopted a similar ban on midday work.[14] The ban applies to migrant workers in outdoor jobs such as construction and hospitality but its potential to prevent occupational injuries, especially among at-risk migrant workers, remains unknown. In this paper, we investigated whether the summer ban

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on midday work policy affects the risk of occupational injuries during the months June–August from extreme hot temperatures in Kuwait.

METHODS

Data

We collected daily claims of occupational injuries reported to the Occupational Health Administration (OHA), Ministry of Health (MOH), Kuwait, for five calendar years from 2015 to 2019. Only occupational injuries in the private sector (including the petroleum industry) are reported. When a private sector worker in Kuwait is injured, they are taken to a private hospital to be treated based on their employer-sponsored health insurance. Workers' compensation claims follow from the hospital-issued medical report provided to OHA and MOH and subsequent adjudication between the insurance company and the employer. In 2019, private sector non-Kuwaiti workers were estimated to represent more than 65% of the total non-Kuwaiti workforce.[15] Claims data from government employees, domestic workers and workers in the informal economy follow different reporting pathways outside OHA and MOH and were excluded from the present study. Therefore, the data examined here may under-report the number of injuries, a common shortcoming of occupational health and safety surveillance data.[16] An injury case is defined as any workers' claim for a physical harm that happened in the workplace or in the commute to/from the workplace and subsequently reported to OHA at the ministry.

We constructed counts of occupational injuries during the summer ban on midday work from 1 June to 31 August in each of the 5 years.

Daily mean temperatures (24-hour average in °C), maximum and minimum temperature (the highest and lowest temperature observed in a 24-hour day in °C), and relative humidity (24-hour average in %) data were obtained from the meteorological services in Kuwait International Airport for the same study period.

Statistical analysis

In order to assess the short-term relationship between summer temperatures and injuries, we fitted generalised additive models (GAM) with a negative binomial distribution in a time series design. The time series design allows for estimation of acute outcomes that cannot by biased by individual characteristics such as age, comorbidities, body mass index, etc, because the design uses 'day' rather than the individual as the unit of analysis (in addition to the fact that these individual characteristics cannot be related to measured temperatures). A 3-day, 5-day and 7-day moving average of daily mean temperature was modelled with penalised splines adjusted for relative humidity, time trend and day of the week.

$$\begin{aligned}\log\left(\mathrm{E}\left[\mathrm{injuries_i}\right]\right) &= \mathrm{intercept} + \mathrm{s}\left(\mathrm{T_{li}}\right) + \mathrm{s}\left(\mathrm{RH_i}\right)\\ &+\mathrm{ns}\left(\mathrm{Time_i},\ \mathrm{df} = 3\ \mathrm{per\ summer}\right)\\ &+\mathrm{Day\ of\ the\ Week_i}\end{aligned}$$

Where for each day i, the expected count of injuries is the outcome of interest; T is average temperature of the day with l days of moving average lag; RH is same day relative humidity; Time is a continuous seasonality control of day of the year modelled with a natural spline (*ns*) with 3 df per summer or year; and a categorical variable for day of the week (Sunday to Monday). Temperature and relative humidity were both modelled with penalised splines (*s*) that allows flexible non-linearity in the exposure–response relationship guided by goodness-of-fit. The advantage of these splines is that they allow a smoothing but avoid both underfitting or overfitting the data.[17] We report the relative risk (RR) of injury compared with the 10th percentile of summer temperatures in Kuwait. Akaike information criterion was used to evaluate model fitness.

Sensitivity

We conducted a number of sensitivity analyses. First, we used the hourly maximum temperature instead of the daily average temperature. Second, we used 'heat index' which is an integrated measure of temperature and humidity.[18] Third, we fitted distributed lag non-linear models (DLNM)[19] for up to 7 days of lag to allow flexibility in modelling the lag dimension. Fourth, for a tight control over seasonality, we tried a case-crossover design instead of time series.[20] Fifth, we used all injuries across the year and included an indicator variable (1 or 0) for the months where the policy was implemented (June to August vs other months of the year) to evaluate whether a ban on midday work in the three summer months reduced injuries after adjusting for seasonality. Details of the models used for the five sensitivity analyses are provided in online supplemental methods.

All analyses were conducted using R (V.4.2.1). The penalised splines were implemented in GAMs using the mgcv package.[21]

RESULTS

Descriptive

Across all reported occupational injuries, 95.7% were men and 96% were non-Kuwaiti migrant workers. The average age was 42.3 years (SD 10.4 years). In the summer months of June, July and August, there were a total of 3710 reported occupational injuries in 5 years between 2015 and 2019, with an average of 742 injuries per summer. The most frequent cause of injury was fall from height (18.3%), followed by fall from the same level (16.6%) and heavy object fall (14.7%). A breakdown of injuries by cause is provided in online supplemental table 1S. The highest number of injuries were reported in the summer of 2016 (n=818 injuries). There were, on average, 7.2, 7.6 and 9.4 reported injuries per day in the summer months of June, July and August, respectively (table 1).

Meteorological variables are summarised in table 1. The average 24-hour temperature during the summer months was 39.4°C (SD: 1.84°C). The relative humidity for the corresponding period was on average 17.9% (SD: 8.20%). Maximum hourly recorded temperatures in a given day during the summer months of Kuwait ranged from 38.1°C to 51.7°C. The percentiles and distributions of daily 24-hour average and the maximum hourly temperature per day are shown in table 1 and figure 1.

Regression

The smoothed temperature-injury exposure-response relationship was approximately S-shaped. That is, the risk of injuries increases initially as summer temperatures increase until it stabilises and then starts declining at extremely hot temperatures (figure 2). The shape of the curve was consistent across the choice of moving average days. However, the model with 7-day moving average provided the best fit. Results from stratified regression by the most common causes of injury were not different from the overall pattern of injuries (online supplemental figure 1S).

Using 7-day moving averages, compared with the 10th percentile of summer temperatures in Kuwait (37.0°C), the average summer day with temperature of 39.4°C increased the relative risk of injury to 1.44 (95% CI 1.34 to 1.53). Similarly, temperatures of 40°C and 41°C were associated with relative risks of

Table 1 Descriptive statistics for occupational injuries and meteorology in the summer months ban of midday work (June–August) for the period from 2015 to 2019

	June	July	August	Overall
Injuries average (per day)				
Mean (SD)	7.2 (6.5)	7.6 (6.3)	9.4 (7.8)	8.1 (6.9)
Median (min, max)	7.5 (0, 30)	8.0 (0, 25)	11.0 (0, 28)	9.0 (0, 30)
Temperature 24-hour average (°C)				
Mean (SD)	38.7 (2.0)	40.2 (1.6)	39.4 (1.7)	39.4 (1.8)
Min	33.6	35.7	35.1	33.6
1st	34.1	36.7	35.5	34.6
5th	35.0	37.7	36.7	36.3
10th	36.1	38.3	37.1	37.0
25th	37.5	39.1	38.2	38.3
50th (median)	38.8	40.0	39.4	39.5
75th	40.2	41.3	40.6	40.7
90th	41.1	42.3	41.5	41.9
95th	42.1	42.7	42.1	42.3
99th	42.6	43.1	42.7	43.0
Max	43.1	43.5	43.1	43.5
Maximum hourly temperature (°C)				
Mean (SD)	46.0 (2.5)	47.5 (1.8)	47.3 (1.7)	47.0 (2.1)
Median (min, max)	46.1 (38.1, 51.6)	47.6 (42.2, 51.7)	47.3 (42.2, 51.3)	47.1 (38.1, 51.7)
Relative humidity (%)				
Mean (SD)	15.3 (4.8)	16.6 (7.2)	21.6 (10.2)	17.9 (8.2)
Median (min, max)	14.3 (9.1, 50.6)	14.6 (8.7, 56.8)	17.5 (9.8, 62.2)	15.2 (8.7, 62.2)

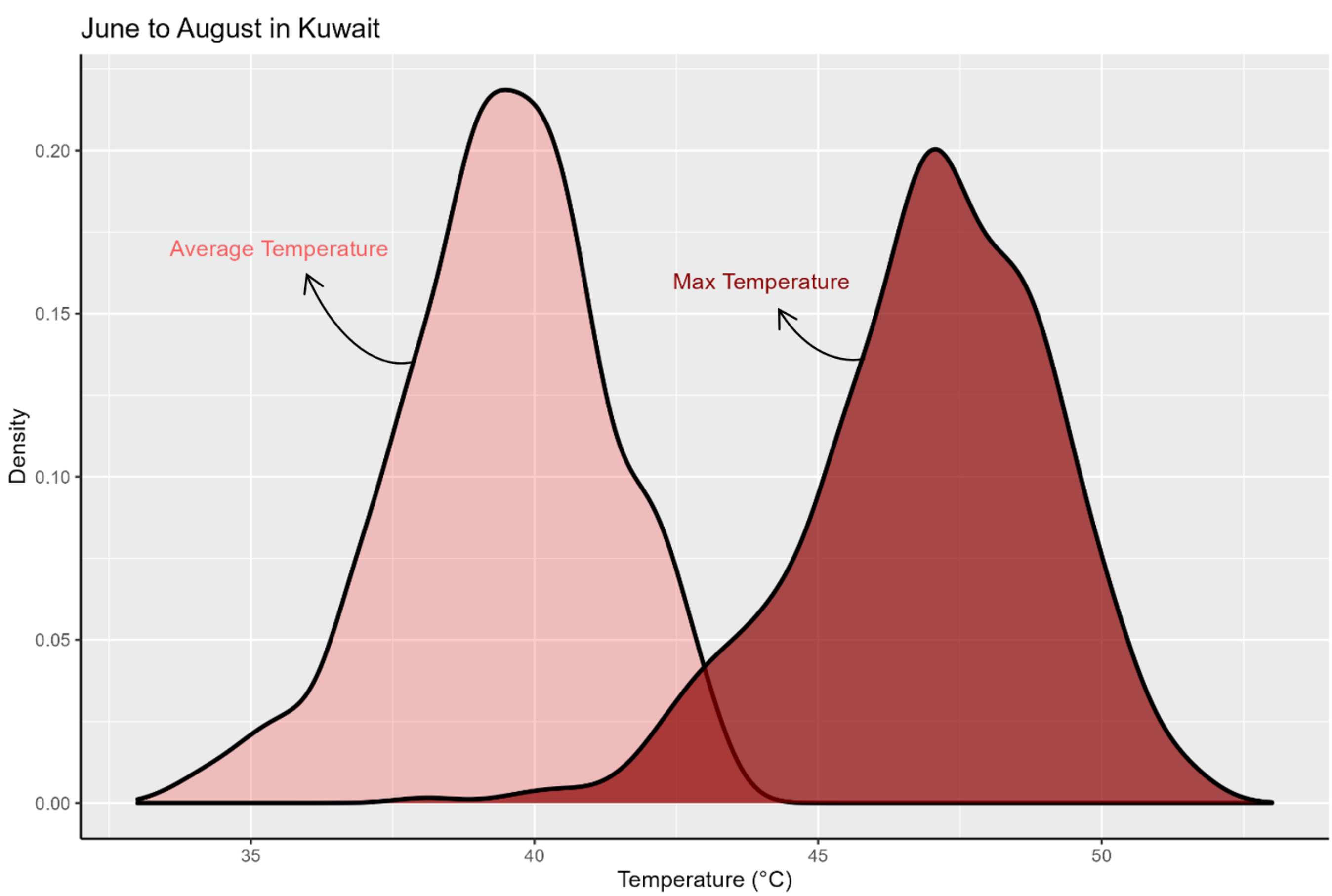

Figure 1 Distribution of daily mean and maximum temperatures during the summer months ban on midday work (June to August) in Kuwait for the period from 2015 to 2019. Y-axis is the density function for the kernel density estimation.

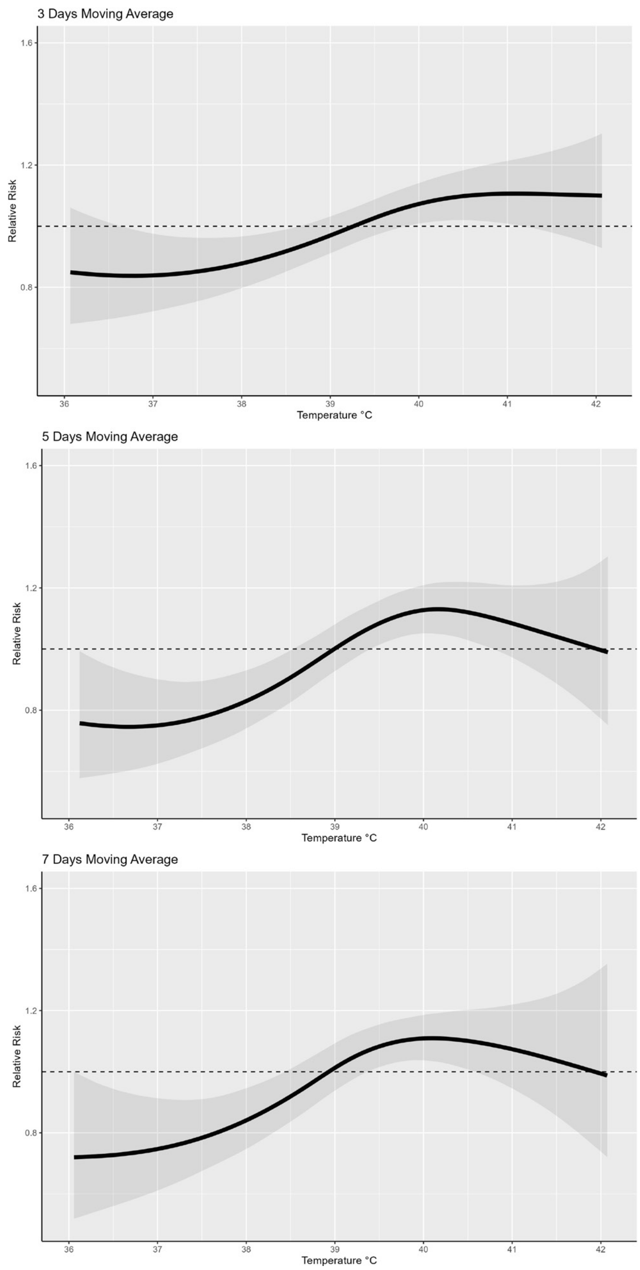

Figure 2 Exposure–response curves for 3-day, 5-day and 7-day moving average of daily mean temperatures and relative risks of occupational injuries during the summer months ban on midday work (June–August) in Kuwait for the period from 2015 to 2019.

1.48 (95% CI 1.39 to 1.59) and 1.44 (95% CI 1.27 to 1.63), respectively. The risks levelled off at 42°C, the 90th percentile of summer temperatures (RR 1.33; 95% CI 0.99 to 1.79). Other choices of moving average produced similar results (table 2).

Sensitivity

The results were consistent across sensitivity analysis models. Using maximum temperature or a composite exposure such as the heat index resulted largely in similar inferences (online supplemental figure 2S, 3S). Using case-crossover design instead of time series or fitting temperature with DLNMs instead of moving averages also showed a similar pattern, although with wider uncertainty (online supplemental figure 4S, 5S). Finally, an indicator variable for the summer months versus the rest of the months was not statistically significant after accounting for seasonality (p=0.61).

Table 2 Relative risks of occupational injury from 3-day, 5-day and 7-day moving average of daily mean temperatures during the summer months ban on midday work (June–August) in Kuwait for the period from 2015 to 2019

	3-day temperature Moving average	5-day temperature Moving average	7-day temperature Moving average*
	Relative risk (95% CI)		
37.0°C (10th percentile)	1 (reference)	1 (reference)	1 (reference)
38.0°C	1.05 (0.95 to 1.15)	1.11 (0.99 to 1.24)	**1.13 (1.00 to 1.27)**
39.0°C	**1.16 (1.09 to 1.23)**	**1.33 (1.24 to 1.44)**	**1.36 (1.26 to 1.46)**
39.4°C (mean)	**1.21 (1.14 to 1.28)**	**1.43 (1.33 to 1.53)**	**1.44 (1.34 to 1.53)**
40.0°C	**1.28 (1.20 to 1.36)**	**1.50 (1.40 to 1.61)**	**1.48 (1.39 to 1.59)**
41.0°C	**1.32 (1.20 to 1.45)**	**1.44 (1.30 to 1.61)**	**1.44 (1.27 to 1.63)**
42.0°C (90th percentile)	**1.31 (1.12 to 1.54)**	**1.33 (1.03 to 1.71)**	1.33 (0.99 to 1.79)

Temperature was fitted with penalised splines; all models were adjusted for seasonality, day of the week and relative humidity.
Values in bold represent statistically significant effect estimates (p<0.05).
*This model provided the lowest AIC.
AIC, Akaike information criterion.

DISCUSSION

Here, we find that extreme heat exposure was associated with increased risk of occupational injuries in the hot summers of Kuwait. The exposure–response relationship between heat and injury observed here, in which risk increases with temperature up to a plateau and then declines at extreme temperatures was somewhat consistent with prior studies,[22–24] although recent studies in Europe now show a U-shape relationship with no decline at the very hot temperatures.[25 26] The decline is likely due to healthy worker survivor bias, where healthier workers tolerate very high exposure whereas unhealthy workers might stop working. Another possible explanation is the rule-of-thumb practice, although an unwritten law, that work in Kuwait must stop when temperature reaches 50°C. Nevertheless, the magnitude of the relative risks of injury for every 1°C increase in Kuwait was higher than previously reported in other countries, but on par with relative risks of injury from heatwaves.[9] This greater risk could result from Kuwait's relatively hotter summers in comparison to other study sites.

Gulf countries in the Arabian Peninsula (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates) are known for their inherently harsh, desert, hyperarid and hot climates. In a warming climate, millions of workers in this region may find days too hot to work safely.[14] Migrant workers constitute >80% of Kuwait's formal workforce.[27] The percentage may be higher due to undercounting of informal and precarious jobs. Migrant labourers typically work in poorer and tougher conditions than their Kuwaiti national counterparts. Migrant labourers may be more likely to lack access to cooling facilities, whether on site or at home, rendering them more vulnerable to heat exposure, especially as they may be more likely to have worse baseline health status as well.[5 28–31] Careful considerations for susceptible groups, such as migrant workers, are desperately needed. For example, comprehensive occupational safety and health programmes with assessment and management components must be at least made available in different languages that could facilitate better communication with migrant workers. Empowering migrant workers to self-pace is unlikely to happen without abolishing abusive job restriction policies such as those of the 'kafala' system.[32] In addition, engineering and administrative controls must ensure cultural and language appropriate training and education for recognition of heat exhaustion/stroke symptoms and first aid as well as provision of fluids and shaded rest stations. Despite a rapidly warming climate and already apparent excess harms from heat exposure, the science of heat standards for workers is still lagging. The WHO and the International Labour Organization do not have any standards for occupational heat. Even in the USA, the Occupational Safety and Health Administration (OSHA) does not yet have a heat standard, although its rulemaking process was recently initiated.

In this vacuum of heat policies, policy-makers in Gulf countries adopted a ban on midday work from June to August. This simplistic approach may not be as protective as policy-makers envisioned on at least three accounts. First, it assumes the risk from heat is contained within these 3 months. Extreme heat has occurred in May and September, and, owing to climate change, may do so more frequently. Second, the midday time window is somewhat arbitrary and may not coincide with peak heat risk. A heat stress exposure assessment study in one region in Saudi Arabia, found that the highest intensity of outdoor exposure for workers was actually from 9:00 to 12:00 hours.[33] Third, the policy does not consider any measurable risk metric. Occupational heat stress is a function of environmental factors (eg, temperature, relative humidity, wind speed, sunlight), workplace factors (eg, clothing, metabolic rate) and personal factors (eg, acclimatisation, pre-existing conditions and health status). None of these are factored in the blanket calendar-based policy. Given these limitations, it was not surprising to observe an increase in injury risk with heat exposure despite the ban on midday work.

Beyond the optimal time of day to curtail work, best practice for policy-making around occupational protections for heat exposure should also consider how heat is measured. The wet bulb globe temperature (WBGT) jointly assesses ambient temperature, humidity, wind speed and solar radiation[34] and has been extensively studied by the US Army[35] to protect soldiers from heat exposures in the Middle East and other hot regions. Occupational thresholds (based on WBGT) were more formally developed by the American Conference of Governmental Industrial Hygienists and the National Institute for Occupational Safety and Health through their threshold limit value and recommended exposure level, respectively.[36 37] These risk-based estimates also incorporate the estimated metabolic rate due to work effort, clothing and, in some cases, acclimatisation status of workers.

In addition to identifying critical thresholds, any effort to implement a risk-based heat standard must also include elements of adequate water intake and shaded rest along to be effective.[38] Heat prevention programmes include elements of empowering workers to do self-paced work, education, compliance assistance and stakeholder engagement.[39 40] In most cases, these programmes are not legally enforced and are continuously evolving with more evidence. For example, the OSHA flagship awareness campaign of 'Water. Rest. Shade.' (https://www.osha.gov/heat) was recently updated in 2021 to recognise indoor heat hazards and address other acclimatisation programmes. While strategies to implement such programmes can be challenging, the status-quo in Kuwait and the Middle East, however, is obviously more problematic.

This study has several limitations. First, the counts of injuries are certainly underestimated. Under-reporting is a common problem in studies that use a registry-like dataset such as what we had or the workers' compensation data in North America.[16] Assuming this undercount is not associated with the measured exposure, the results we have may be attenuated due to non-differential bias. Second, while temperatures measured at the airport are likely to be a good proxy for Kuwait's metropolitan areas, daytime and night-time temperatures in Kuwait may differ spatially away from urban areas, although not substantially.[41] In addition, as we relied on ambient temperatures and relative humidity, we did not have location specific measurements of other factors that could induce heat stress (eg, shading, air movement). This could introduce non-differential measurement error in the exposure. Third, there was no information available on the type of industry (eg, Standard Industrial Classification codes) associated with each injury that would permit consideration of where the priority of health and safety problems are located. Finally, we were not able to formally assess the effectiveness nor the extent of implementation of the policy in a pre/post analysis because we had no data prior to 2015 and no data on violations of the policy. However, we saw no reduction in risk of injuries in June to August versus other months of the year, after removing (adjusting for) the effects of seasonality.

CONCLUSIONS

We found substantial increases in occupational injury risk from extremely hot temperatures despite the ban on midday work policy in Kuwait. While popular in the region and easy to implement, calendar-based regulations may be inadequate to provide occupational heat protections, especially for migrant workers. Evidence-based heat standards are needed to protect all workers, but especially migrant workers who may face inequitable harms from more extreme heat brought by climate change.

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REFERENCES

1 World Meteorological Organization. Press release: 2021 one of the seven warmest years on record, WMO consolidated data shows. 2022. Available: https://public.wmo.int/en/media/press-release/2021-one-of-seven-warmest-years-record-wmo-consolidated-data-shows
2 Pal JS, Eltahir EAB. Future temperature in southwest asia projected to exceed a threshold for human adaptability. *Nature Clim Change* 2016;6:197–200.
3 Safieddine S, Clerbaux C, Clarisse L, *et al*. Present and future land surface and wet bulb temperatures in the arabian peninsula. *Environ Res Lett* 2022;17:044029.
4 Alahmad B, Vicedo-Cabrera AM, Chen K, *et al*. Climate change and health in kuwait: temperature and mortality projections under different climatic scenarios. *Environ Res Lett* 2022;17:074001.
5 Alahmad B, Shakarchi AF, Khraishah H, *et al*. Extreme temperatures and mortality in kuwait: who is vulnerable? *Sci Total Environ* 2020;732:139289.
6 Vainio H. Changing work and workers' health in the 21st century – a view from kuwait. International Labor Organization (ILO); 2019. Available: https://www.ilo.org/global/topics/safety-and-health-at-work/events-training/events-meetings/world-day-for-safety/33thinkpieces/WCMS_680030/lang--en/index.htm
7 Flouris AD, Dinas PC, Ioannou LG, *et al*. Workers' health and productivity under occupational heat strain: a systematic review and meta-analysis. *Lancet Planet Health* 2018;2:e521–31.
8 Spector JT, Masuda YJ, Wolff NH, *et al*. Heat exposure and occupational injuries: review of the literature and implications. *Curr Environ Health Rep* 2019;6:286–96.
9 Fatima SH, Rothmore P, Giles LC, *et al*. Extreme heat and occupational injuries in different climate zones: A systematic review and meta-analysis of epidemiological evidence. *Environ Int* 2021;148:106384.
10 Kenny GP, Notley RP, Flouris AD, *et al*. Climate change and heat exposure: impact on health in occupational and general populations. In: Adams WM, Jardine JF, eds. *Exertional Heat Illness: A Clinical and Evidence-Based Guide*. Cham: Springer International Publishing, 2020: 225–61.
11 Moyce SC, Schenker M. Migrant workers and their occupational health and safety. *Annu Rev Public Health* 2018;39:351–65. 10.1146/annurev-publhealth-040617-013714 Available: https://www.annualreviews.org/toc/publhealth/39/1
12 Preibisch K, Otero G. Does citizenship status matter in Canadian agriculture? workplace health and safety for migrant and immigrant laborers. *Rural Sociol* 2014;79:174–99. 10.1111/ruso.12043 Available: http://doi.wiley.com/10.1111/ruso.2014.79.issue-2
13 Public Authority of Manpower. *Ministerial decree no.535 for the year 2015 regarding working hours in open spaces*. 2015.
14 International Labour Organization. *Working on a warmer planet: the impact of heat stress on labour productivity and decent work*. Geneva: International Labour Office, 2019.
15 Central Statistical Bureau. *Migration statistics bulletin. government of kuwait*. 2021.
16 Nadalin V, Smith PM. Examining the impact of occupational health and safety vulnerability on injury claim reporting in three Canadian provinces. *Am J Ind Med* 2020;63:435–41.
17 Wood SN, Pya N, Säfken B. Smoothing parameter and model selection for general smooth models. *Journal of the American Statistical Association* 2016;111:1548–63.
18 Anderson GB, Bell ML, Peng RD. Methods to calculate the heat index as an exposure metric in environmental health research. *Environ Health Perspect* 2013;121:1111–9.
19 Gasparrini A, Armstrong B, Kenward MG. Distributed lag non-linear models. *Stat Med* 2010;29:2224–34.
20 Armstrong BG, Gasparrini A, Tobias A. Conditional Poisson models: a flexible alternative to conditional logistic case cross-over analysis. *BMC Med Res Methodol* 2014;14:122.
21 Wood S, Wood MS. *Package' ' 'mgcv. R package version*. 2015.
22 Xiang J, Bi P, Pisaniello D, *et al*. Association between high temperature and work-related injuries in Adelaide, South Australia, 2001-2010. *Occup Environ Med* 2014;71:246–52.
23 Basagaña X. High ambient temperatures and work-related injuries. *Occup Environ Med* 2014;71:231.
24 Morabito M, Cecchi L, Crisci A, *et al*. Relationship between work-related accidents and hot weather conditions in Tuscany (central Italy). *Ind Health* 2006;44:458–64.
25 Martínez-Solanas È, López-Ruiz M, Wellenius GA, *et al*. Evaluation of the impact of ambient temperatures on occupational injuries in Spain. *Environ Health Perspect* 2018;126:067002.
26 Marinaccio A, Scortichini M, Gariazzo C, *et al*. Nationwide epidemiological study for estimating the effect of extreme outdoor temperature on occupational injuries in italy. *Environ Int* 2019;133(Pt A):105176.
27 Migrants & Refugees Section. Country profiles: kuwait. 2021. Available: https://migrants-refugees.va/country-profile/kuwait-2/
28 Alahmad B, AlMekhled D, Odeh A, *et al*. Disparities in excess deaths from the COVID-19 pandemic among migrant workers in Kuwait. *BMC Public Health* 2021;21:1668.
29 Hamadah H, Alahmad B, Behbehani M, *et al*. COVID-19 clinical outcomes and nationality: results from a nationwide registry in Kuwait. *BMC Public Health* 2020;20:1384.
30 Alahmad B, Kurdi H, Colonna K, *et al*. COVID-19 stressors on migrant workers in Kuwait: cumulative risk considerations. *BMJ Glob Health* 2020;5:e002995.
31 Achilleos S, Al-Ozairi E, Alahmad B, *et al*. Acute effects of air pollution on mortality: a 17-year analysis in kuwait. *Environ Int* 2019;126:476–83.
32 Wegman DH, Neupane D, Sharma S, *et al*. Dying for sport. *Occup Environ Med* 2022;79:73–4.
33 Al-Bouwarthan M, Quinn MM, Kriebel D, *et al*. Assessment of heat stress exposure among construction workers in the hot desert climate of Saudi Arabia. *Ann Work Expo Health* 2019;63:505–20.
34 Occupational Safety and Health Administration. *Heat stress*. OSHA, United States Department of Labor, 2017.
35 US Army Research Institute of Environmental Medicine (USARIEM). *Heat stress control and heat casuality management*. Washington D.C: US Department of the Army and Airforce, 2003.
36 National Institute for Occupational Safety and Health (NIOSH). *Occupational exposure to heat and hot environments*. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, 2016.
37 American Conference of Governmental Industrial Hygienists (ACGIH). *Heat stress and strain: TLV®7th edition documentation*. Cincinnati, OH: ACGIH, 2017.
38 Glaser J, Hansson E, Weiss I, *et al*. Preventing kidney injury among sugarcane workers: promising evidence from enhanced workplace interventions. *Occup Environ Med* 2020;77:527–34.
39 Hansson E, Glaser J, Weiss I, *et al*. Workload and cross-harvest kidney injury in a Nicaraguan sugarcane worker cohort. *Occup Environ Med* 2019;76:818–26.
40 Pacheco-Zenteno F, Glaser J, Jakobsson K, *et al*. The prevention of occupational heat stress in sugarcane workers in nicaragua-an interpretative phenomenological analysis. *Front Public Health* 2021;9:713711.
41 Alahmad B, Tomasso LP, Al-Hemoud A, *et al*. Spatial distribution of land surface temperatures in Kuwait: urban heat and cool islands. *Int J Environ Res Public Health* 2020;17:2993.